VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

December 1, 2022

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United States Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D. C. 20555

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VIRGINIA ELECTRIC AND POWER COMPANY
SURRY POWER STATION UNITS 1 AND 2
LICENSE AMENDMENT REQUEST FOR NRC APPROVAL OF METHODOLOGY CHANGE AND RECLASSIFICATION OF THE TURBINE BUILDING AS A TORNADO RESISTANT STRUCTURE
SUPPLEMENTAL INFORMATION

By letter dated April 14, 2021 [Serial No. 21-330, Agencywide Documents Access and Management System (ADAMS) Accession No. ML22104A125], Virginia Electric and Power Company (Dominion Energy Virginia) submitted a license amendment request (LAR) for Surry Power Station (SPS) Units 1 and 2 requesting NRC approval of a methodology change and reclassification of the turbine building as a tornado resistant structure in the SPS Updated Final Safety Analysis Report (UFSAR). The reclassification is based on using a different methodology and acceptance criteria than those defined for other SPS tornado resistant (i.e., Tornado Criterion "T") structures. The new methodology and acceptance criteria are considered a change to a method of evaluation that requires prior NRC approval per 10 CFR 50.59(c)(2)(viii).

By letter dated September 15, 2022 (ADAMS Accession No. ML22250A467), the NRC requested a regulatory audit to increase the NRC staff's understanding of the LAR and to identify any information that may require docketing to support the NRC staff's regulatory finding. In support of the audit, Dominion Energy Virginia uploaded supporting technical information to a shared electronic reading room to facilitate the NRC's review, including calculations, plant drawings, engineering evaluations, etc. A conference call was held on October 18, 2022, between the NRC and Dominion Energy Virginia personnel to discuss the results of the NRC's audit. At the conclusion of the call, it was agreed that Dominion Energy Virginia would provide docketed supplemental information to facilitate the completion of the NRC staff's technical review. The requested supplemental information is provided in the attachment.

If you have any questions or require additional information, please contact Mr. Gary D. Miller at (804) 273-2771.

Respectfully,

James E. Holloway
Vice President – Nuclear Engineering and Fleet Support

Commitments made in this letter: None

Attachment: Supplemental Information

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Mr. James E. Holloway, who is Vice President - Nuclear Engineering and Fleet Support, of Virginia Electric and Power Company. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 1st day of December, 2022.

My Commission Expires: 12/31/24

CRAIG D SLY
Notary Public
Commonwealth of Virginia
Reg. # 7518653
My Commission Expires December 31, 2024

Notary Public

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Attachment

SUPPLEMENTAL INFORMATION

LICENSE AMENDMENT REQUEST FOR NRC APPROVAL OF METHODOLOGY CHANGE AND RECLASSIFICATION OF THE TURBINE BUILDING AS A TORNADO RESISTANT STRUCTURE

Virginia Electric and Power Company
(Dominion Energy Virginia)
Surry Power Station Units 1 and 2

SUPPLEMENTAL INFORMATION

LICENSE AMENDMENT REQUEST FOR NRC APPROVAL OF METHODOLOGY CHANGE AND RECLASSIFICATION OF THE TURBINE BUILDING AS A TORNADO RESISTANT STRUCTURE

NRC CIVIL/STRUCTURAL AUDIT INFORMATION REQUESTS:

The proposed LAR states that SPS was not subject to General Design Criteria (GDC) requirements, however, the proposed LAR notes that the Turbine Building meets the intent of GDC 2 and GDC 4. The staff has the following questions to determine if the proposed LAR meets the intent of GDC 2 and GDC 4.

1. *Section 3.2 (Tornado missiles)*

Explain how safety-related components and systems within the Turbine Building are protected from the tornado generated missiles after the Turbine Building Steel Superstructure (TBSS) collapses during the postulated tornado wind event.

Dominion Energy Virginia Response

The LAR seeks permission to reduce the maximum tornado wind speed applicable to the Surry Power Station (SPS) Units 1 and 2 Turbine Building (TB) from 360 miles per hour (mph) to 250 mph. Allowing for this reduction, the operating and mezzanine elevation reinforced concrete decks are demonstrated not to collapse and will remain stable under the proposed maximum 250 mph tornado wind speed. The stability of the operating and mezzanine decks provides protection to safe shutdown and non-isolable water source components located within the basement of the TB against falling members during the collapse of the roof structure.

Safe shutdown and non-isolable water source components located in the TB basement that are potentially vulnerable to tornado missiles were identified as part of the SPS response to NRC Regulatory Issue Summary RIS-2015-06, *Tornado Missile Protection*. To resolve these non-conforming tornado missile vulnerability concerns, a probabilistic risk assessment (PRA) was implemented per NEI 17-02, Rev. 1B, "Tornado Missile Risk Evaluator (TMRE) Industry Guidance Document," at SPS. The scope of TMRE components within the TB structure is limited to Circulating Water (CW) and Service Water (SW) valves, which constitute the largest contributors to risk since a rupture of the CW and SW piping can create internal flooding that could result in core damage to both units. Exposed equipment failure probabilities (EEFP) were calculated for each of the components listed below following the guidance of NEI 17-02, which accounts for any physical cover that can be credited. For components with no physical cover, the failure probability was taken as 100%.

TMRE Scope in the SPS TB:

- Unit 1 & Unit 2 Circulating Water MOVs in the Inlet Valve Pits
  - 1-CW-MOV-106A/B/C/D (Condenser CW Inlet MOVs)
  - 2-CW-MOV-206A/B/C/D (Condenser CW Inlet MOVs)

- Unit 1 & 2 "A" Service Water Valve Pits
  - 1-SW-MOV-103A/B/C/D (Recirculation Spray Heat Exchanger [RSHX] SW Supply MOVs)
  - 1-SW-MOV-101A/B (Bearing Cooling Heat Exchanger [BCHX] SW Supply MOVs)
  - 1-SW-54 (RSHX SW Supply Head Isolation A & B Sump Drain)
  - 1-SW-41 (RSHX SW Supply Head Isolation C & D Sump Drain)
  - 2-SW-MOV-203A/B/C/D (RSHX SW Supply MOVs)
  - 2-SW-MOV-201A/B (BCHX SW Supply MOVs)
  - 2-SW-11 (Mechanical Equipment Room [MER] 3 SW Inlet Header Root Valve)
  - 2-SW-474 (MER 3 & 4 SW Supply Isolation)

- Unit 1 & 2 "B" SW Valve Pits
  - 1-SW-MOV-102A/B (Component Cooling Heat Exchanger [CCHX] SW Supply)
  - 1-SW-495 (Control Room Chiller SW Supply Header Isolation)
  - 2-SW-MOV-202A/B (SW Supply to River Water Makeup Pumps)

- Unit 1 & 2 CW Manways
  - 1-CW-FNG-1/2/4 (30" Access to 96" A/B/D CW Inlet Piping)
  - 2-CW-FNG-101/102/103/104 (30" Access to 96" A/B/C/D CW Inlet Piping)

Potential adverse effects from tornado missile strikes to the above safe shutdown and non-isolable water source components have been evaluated by the TMRE methodology and determined to be acceptable.

Other safety-related equipment in the TB basement, such as the CCHXs, as well as non-safety related components important to safety, such as Instrument Air Compressors, were identified to have acceptable levels of protection against the local effects (i.e., penetration) from tornado missiles based upon cover provided by overhead steel plates (at least 1" thick) and / or reinforced concrete slabs (at least 12" thick).

SPS Updated Final Safety Analysis Report (UFSAR), Table 15.2-1, delineates plant equipment (systems and components) that are physically protected against the effects of tornados either by location within tornado-resistant structures or by being buried to a sufficient depth. These systems and components are designated "P" and will not fail during a design tornado. Plant systems and components that are not physically protected from tornado-generated missiles, but have been evaluated using the TMRE methodology, are designated as "P*" in Table 15.2-1.

2. *Section 3.3.1.1 (Roof structure collapse scenario)*

The LAR notes that the impact of the falling roof structure on the operating deck was addressed by adding a distributed weight across the operating floor. No discussion is provided about the possibility of a perforation of the operating deck slab or grating. Provide the evaluation of potential impacts of the overhead cranes on local effects (i.e., perforation) of the operating deck or supporting grating, and on the safety-related components and systems within the Turbine Building after the Turbine Building Steel Superstructure (TBSS) collapses during the postulated tornado wind event.

Dominion Energy Virginia Response

The SPS TB overhead cranes, in their current, unanchored condition, will not fall from their crane rails until tornado wind speeds exceed 250 mph, which is aligned with the requested maximum tornado wind speed in the SPS LAR. Upon approval of the LAR, there will be no adverse local effects to safe shutdown or non-isolable water source components located in the TB basement from postulated falling cranes at the requested maximum tornado wind speed of 250 mph. A more detailed discussion of the tornado wind evaluations performed for the LAR and an explanation of the associated SPS TB Steel Superstructure (TBSS) roof collapse scenario is provided below.

The original SPS TBSS evaluations, upon which the LAR is based, have determined the most severe tornado wind loading occurs under east-west direction tornado winds, i.e., causes weak axis bending on TB supporting columns, after the TB exterior siding has blown off, thus directly exposing the bare structural steel members and major components located above grade elevation to tornado wind forces. By design, the SPS TB siding is specified to blow off when tornado wind speeds exceed 150 mph. The original evaluations conservatively assumed the SPS TB overhead cranes were externally anchored to their crane rails within the end bays of the TB, which is where the cranes are normally parked when not in use. This assumption was based upon a review of plant drawings, which shows crane lock details attached to the crane trollies and crane rail beams. This assumption is conservative, since externally anchored cranes can transmit their full tributary tornado wind reactions to the crane rails, which must be carried by the rest of the TBSS, while unanchored cranes can only transmit a maximum crane rail reaction equal to their static wheel-to-rail friction force.

Under the conservative assumption that the SPS TB overhead cranes were externally anchored to their crane rails, the original evaluations concluded that TB roof trusses would begin to break apart and fall upon the operating deck when tornado wind speeds exceeded 180 mph. Failure of the roof trusses allows greater lateral displacements to occur in the supporting crane rail columns, which allows greater lateral translations to occur in the operating deck below. Greater translation in the operating deck allows closure of the isolation gaps in the direction of tornado wind forces. Isolation gaps exist all around the turbine pedestals to provide vibration isolation between the operating deck

and the turbine pedestals. Once the isolation gaps close, the operating deck bears against the turbine pedestals, and the cantilever lengths of the supporting steel columns of the SPS TBSS will shorten as the fixed-end location of maximum moment in the columns will move upwards from grade elevation (EL. 27'-0") to the top of the operating deck elevation (EL. 58'-6"). The shortening of the column cantilever length provides additional resistance against tornado wind forces.

The original evaluation concluded the supporting columns would remain stable until yielding was initiated in the columns at the top of the operating deck when tornado wind speeds exceeded 240 mph. Under the initiation of column yielding at a tornado wind speed of 240 mph, the supporting columns were conservatively assumed to become unstable and fail upon the operating deck, dropping all remaining roof trusses, crane rails and cranes upon the operating deck as well. The failure of all SPS TBSS members above the operating deck elevation was analytically modeled by removing these structural members from the computer model and reassigning their dead loads to the remaining portions of the TB operating deck. The dead load of the failed roof members and fallen cranes was distributed to the operating deck over its concrete and grating slab areas. A dynamic load factor was applied to the combined weights of these failed roof members and fallen cranes to represent a global impact live load upon the operating deck. The global impact live load was combined with the remaining TBSS dead loads and tornado wind load corresponding to a 250 mph wind speed acting in the governing east-west direction. The original global evaluations concluded the operating and mezzanine decks of the partially collapsed TBSS would remain stable providing protection from tornado effects for the safe shutdown and non-isolable water source components located in the TB basement.

After completing the original global evaluations of the SPS TBSS, separate evaluations were initiated to study the local effects of the fallen SPS TB overhead cranes. As in the original global evaluations, it was assumed the cranes were externally anchored to the crane rails in the end bays of the SPS TB, which would result in the partial collapse of the TBSS above the operating deck elevation when tornado wind speeds exceeded 240 mph. The separate local effects evaluations concluded the end bays of the TBSS would sustain severe local damage from falling TB overhead cranes, but progressive collapse would not extend beyond the adjacent interior column rows due to the redundancy of the SPS TBSS. Similar to the original global evaluations, the severely damaged members of the end bays were analytically modeled by removing them from the computer model and concurrently applying their dead load, impact live load, and the governing east-west tornado wind load corresponding to a 250 mph wind speed, to the remaining portions of the SPS TBSS.

The local effects evaluations concluded the remaining portions of the SPS TBSS remained stable under a maximum 250 mph tornado wind speed and that no safe shutdown or non-isolable water source components would be directly impacted by the falling cranes or associated local building collapse in the end bays. Further review revealed that a stack of four (4) Safety-Related (SR) cable trays that run through the

Unit 2 end bay have the potential to be adversely impacted by the local building collapse from the falling Unit 2 TB overhead crane. However, the CW and SW components that are fed by the electrical cables in these affected SR cable trays are not located near the end bays of the SPS TB where severe local damage is postulated. Also, it was noted that these SW and CW components may be operated manually if their power is interrupted. Due to their locations away from the severe postulated local damage in the end bays of the SPS TB, the pathway to these components will remain unobstructed so that plant operators can access and manually manipulate these components if necessary. Under the conservative assumption that the SPS TB overhead cranes were externally anchored in the end bays of the TB, the local effects evaluation preliminarily concluded that there would be no breaches of exposed CW or SW components located within the SPS TB basement from falling TB overhead cranes during a tornado. Similarly, no damage would occur to other non-isolable components or adjacent Tornado Criterion "T" structures from postulated crane fall and associated local building collapse during a tornado corresponding to a maximum wind speed of 250 mph.

To confirm the field conditions for these global and local effects evaluations, subsequent walkdowns were performed in the SPS TB. The results of these walkdowns revealed that the TB overhead cranes were not externally anchored as detailed on plant drawings, but instead were free to roll or slide on their crane rails when exposed to the governing east-west tornado winds. If the TB overhead cranes are free to roll or slide, they cannot exert their full tributary wind reactions to the SPS TBSS that were calculated in the original global and local evaluations. A sliding or rolling crane can only exert a maximum tributary tornado wind reaction equal to its static wheel-to-rail friction force under dry conditions of use. The difference between the full tributary 240 mph tornado wind speed reaction, calculated under the assumption of having externally anchored cranes, and the maximum static crane wheel-to-rail friction force that an unanchored crane can exert under dry conditions of use has been conservatively estimated to be 97.7 kips per crane. This difference can be credited back to the supporting steel columns of the TBSS to increase their capacity to withstand forces from tornado wind speeds well above 240 mph. In their current unanchored condition, SPS TB overhead cranes will transfer significantly less tributary wind reactions to the TBSS than were calculated in the original global and local effects evaluations.

By inspection, the estimated 97.7 kips per crane credit to tributary tornado crane rail reactions will sufficiently reduce the tornado wind bending stresses associated with a 240 mph tornado wind speed in the supporting columns of the SPS TBSS to allow the supporting columns to remain stable under tornado wind speeds well above 250 mph. With stable supporting columns in the SPS TBSS under tornado wind speeds above 250 mph, the operating deck of the SPS TBSS will not experience the dead load and dynamic impact effects from falling cranes, crane rails, and columns that were included in the original global and subsequent local effect evaluations, providing further margin for the remaining SPS TBSS. Based on these findings, the conclusions of the original SPS TBSS global and local effects evaluations are conservative and will continue to support

the LAR. Therefore, the SPS TB overhead cranes in their current unanchored condition will not fall from their crane rails until tornado wind speeds exceed 250 mph, which exceeds the requested licensing basis maximum tornado wind speed of 250 mph as requested in the LAR. Upon approval of the LAR, there will be no adverse local effects to safe shutdown or non-isolable water source components located in the TB basement from postulated falling cranes at the requested maximum tornado wind speed of 250 mph.

3. *Section 3.3.1.2 (Finite element modeling approach)*

LAR Section 3.3.1.2 states "A true-stress, true-strain curve for carbon steel was developed based on the method provided in Section VIII, Division 2 of the ASME Boiler and Pressure Vessel Code [Ref. 11] and using the design basis ASTM A36 material strength and properties [Ref. 12]. UFSAR planned changes in the attachment 3 states "Nonlinear material acceptance criteria are based on the applicable requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, 2010 Edition" (Reference 11). Provide the justification for why it is acceptable to use the methodology provided in Section VIII, Division 2 of the ASME Boiler and Pressure Vessel Code in developing the stress-strain curve for A36 carbon steel in the analysis of the Turbine Building.

Dominion Energy Virginia Response

The nonlinear finite element analysis of the TBSS requires the use of a material model that can realistically represent the stress-strain behavior of A36 carbon steel comprising the structural framing of the TBSS. The equations provided in ASME Section VIII, Division 2, were determined to provide a reasonable stress-strain curve for A36 material for the following reasons and were considered in the absence of other readily available codes or standards that can serve this purpose.

- The nominal yield strength and the minimum tensile strength for A36 material based on ASTM A36/A36M were used to represent the onset of yielding and a conservative failure point for A36 material. Therefore, the yield and failure criteria for the material are consistent with realistic material behavior defined by the ASTM A36/A36M standard.

- With the use of nominal yield strength and the minimum tensile strength based on the ASTM A36 standard, the equations in ASME Section VIII, Division 2, define how the material behavior transitions from the yield strength to the ultimate tensile strength within the stress-strain curve. The post-yield behavior of A36 material has minimal impact on the results of the analysis of the TBSS under tornado wind loads because the post-yield material stiffness is a small fraction (less than 1%) of the initial stiffness that the material experiences prior to yielding (i.e., modulus of elasticity).

- Comparison of the stress-strain curve for A36 steel material based on ASME Section VIII, Division 2, with that based on the Johnson-Cook material model indicates that the two material models represent very similar post-yield stiffness reduction with ASME Section VIII, Division 2, model generally showing smaller stresses than those from the Johnson-Cook model at any given plastic strain. Therefore, the A36 material model based on ASME Section VIII, Division 2, results in a conservative estimation of true stresses.

- From analysis results of the TBSS, the maximum strain ratio (i.e., the ratio of the calculated true strain to the minimum elongation based on the ASTM standard for A36 material) is approximately equal to 0.485. Therefore, the most critical steel member of the TBSS still exhibits sufficient capacity margin in terms of calculated strains. This observation confirms that analysis results are not sensitive to the post-yield material behavior (i.e., how the yield point connects to the ultimate point on the stress-strain curve for material behavior).

Therefore, the use of the A36 material stress-strain curve, based on ASME Section VIII, Division 2, is justified as being reasonable and conservative as described above. It should be emphasized that the extent of the use of ASME Section VIII, Division 2, for analysis of the TBSS is limited to the equations provided for construction of the stress-strain curve. The material failure criteria (i.e., ultimate tensile strength and minimum elongation) are obtained from the ASTM standard for A36 material.

4. Section 3.3.1.3 (Applied loads)

Explain how the operating floor is designed for the tornado wind uplift after the Turbine Building Steel Superstructure (TBSS) collapses during the postulated tornado wind event.

Dominion Energy Virginia Response

Tornado wind loads on structures can result from atmospheric differential pressure (vacuum pressure) and velocity pressure. The atmospheric differential pressure occurs due to rotational motion of the air about the center of the tornado which can, in the case of closed or partially vented structures, produce direct differential pressures in addition to the velocity pressure caused by high winds. These two components of the tornado wind pressure are addressed by the characteristics of the design tornado defined in Section 15.2.3 of the SPS UFSAR, as follows:

- Rotational velocity: 300 mph
- Translation velocity: 60 mph
- Pressure drop: 3 psi in 3 sec.

According to Section 15.2.3 of SPS UFSAR, "Structures and systems are checked for tornado pressure loading, vacuum loading, and the combination of these two." As stated, the tornado pressure (i.e., tornado velocity pressure) loading reflects tornado wind loads due to the combined rotational and translational wind velocities, whereas the vacuum loading corresponds to the loading caused by pressure drop (i.e., atmospheric differential pressure or vacuum pressure) of 3 psi in 3 seconds.

The new methodology and acceptance criteria, as requested in the LAR for evaluation of the TB, include the use of a 250 mph maximum tornado wind speed, nonlinear static finite element analysis methodology, and acceptance criteria for evaluation of the TBSS. Using the tornado wind speed of 250 mph, a three-dimensional (3-D) nonlinear finite element modeling approach was employed to evaluate structural performance of the TBSS under the applied tornado wind load. The analysis predicted a roof-collapse scenario in which the roof structure was collapsing due to the yielding of the upper portion of the columns at the operating deck elevation. The analysis conservatively assumed the entire steel roof structure collapses simultaneously on top of the operating deck concrete slab and steel grating areas. The analysis demonstrates the operating and mezzanine decks of the TB remain stable and would provide adequate protection to the safe shutdown and non-isolable water source components located in the TB basement. Also, partial collapse of the TBSS roof structure would not damage adjacent Criterion 'T' structures and the safe shutdown equipment housed therein.

Based on the information in the SPS design specification, the non-structural siding blows off of the building at wind speeds above 150 mph. Therefore, in the analysis of the TBSS the wind was applied directly on the exposed steel columns and girders of the TBSS. The wind pressure load was applied to all exposed steel and concrete surfaces with appropriate drag coefficients. Wind load was also added to the TB to account for the tributary area of rugged, large equipment which is considered to remain in place. The portion of the steel frame above the operating floor at elevation 58'-6" is largely unsupported laterally. Preliminary evaluations indicate that because these steel members are directly exposed to the tornado winds and are significantly more flexible than the rest of the structure, buckling may occur in many of the members. As a result, the evaluation of the TBSS determined that these members would become unstable during the postulated tornado event.

After the metal siding blows off under tornado wind speeds exceeding 150 mph, the TB is open to tornado winds. Therefore, when the siding blows off, the TB is considered sufficiently vented so that vacuum loading due to 3 psi pressure drop in 3 seconds will not occur and no differential pressure loading will be introduced to the remaining TBSS.

However, tornado velocity pressure effects due to the combined rotational and translational velocities of the tornado can potentially impose uplift forces, especially in the case of fully or partially enclosed buildings. SPS UFSAR, Section 15.2.2, accounts for uplift forces under the normal wind loading where it states, "Roofs were designed for uplift

using 1.25 times the wind load taken at the corresponding elevation of the roof." However, the proposed drag coefficient in Section 15.2.2 of the SPS UFSAR reflects the effects of both external and internal wind pressures due to the normal wind loading of partially or fully enclosed structures. For the TB, which is sufficiently vented when the siding blows off, an uplift drag coefficient of 0.5 was selected based on the building's aspect ratios (i.e., height-to-width and height-to-length ratios), as referenced in ASCE 3269. The uplift drag coefficient of 0.5 represents a conservative estimate of the potential wind uplift applied to the TB when the siding blows off. This is further confirmed by Figure 5 of ASCE 3269, which shows the lift coefficient (C_L) for a plate located parallel to the wind is essentially equal to zero. An evaluation of the TBSS reveals the operating and mezzanine decks of the TB can withstand and balance the wind uplift effects by self-weight of the reinforced concrete slabs and by fusion welds that connect metal decking to the structural steel framing. Therefore, the operating and mezzanine decks of the TB remain stable and would provide adequate protection to the safe shutdown and non-isolable water source components located in the TB basement.

5. *Section 3.3.1.4 (Acceptance criteria)*

LAR Section 3.3.1.4 utilizes the acceptance criteria to evaluate steel members of the Turbine Building to ensure steel members are within their ultimate strength design limit. LAR Section 3.3.1.4 utilizes the acceptance criteria that composite reinforced concrete stress is limited to the concrete compressive strength. Clarify the codes used for the design of steel and concrete in the Turbine Building.

Dominion Energy Virginia Response

The original design calculations of the TB used ACI 318-63 for reinforced concrete members and AISC 6th Ed. for structural steel design. However, since the TB was not designed for tornado loads, a new method of evaluation was proposed in the LAR that uses alternative acceptance criteria based on realistic material behavior and applicable industry guidance where available.

The purpose of the finite element analysis of the TBSS that supports the LAR is to demonstrate that the operating and mezzanine decks of the TBSS remain structurally stable under loads due to a 250 mph tornado wind. The stability of the TB operating and mezzanine decks provides tornado protection for safe shutdown and non-isolable water source components located in the TB basement. However, determination of the onset of structural collapse of the TBSS under extreme loading conditions, such as the condition that the TBSS is likely to experience during a 250 mph tornado wind event, would require element stress levels to go beyond what is typically allowable by applicable industry building codes and standards such as ACI 318 and AISC 360. This is expected since the acceptance criteria in building codes are conservatively set to ensure building structures would remain sufficiently safe and undergo stresses well below what they may experience

at the onset of collapse. Therefore, while conservative, the allowable stresses and strengths defined in building codes and standards fail to realistically predict the ultimate capacity of structures right before collapse. However, such an understanding is crucial in the case of the TBSS because the licensing basis for the TB, as described in Table 15.2-1 of SPS UFSAR, states, "*By design, building collapse will not damage any Class I structures and components during earthquake, or tornado-resistant structures and components during tornado.*" To determine if the TB can meet its licensing basis, the extent of structural collapse under the tornado wind load should be estimated first, which as stated earlier, may lead to exceeding allowable stresses and strengths defined in building codes. Therefore, the following acceptance criteria were used to understand the realistic behavior of the TB during a tornado event.

Structural steel members were evaluated based on their material (i.e., A36 carbon steel) behavior and by comparing their maximum principal strain to the minimum elongation of carbon steel per the ASTM A36 standard. Geometric nonlinearities due to large deflection and P-Delta effects and plasticity are also included in the model. As such, any potential failure of steel members due to buckling was included in the analysis and would terminate the analysis if buckling should become an issue.

For reinforced concrete members, both tensile and compressive normal stresses were evaluated and compared against the compressive strength of the concrete material. Therefore, the equivalent membrane plus bending stresses in reinforced concrete members were compared to the in-situ compressive strength of the concrete material. This approach assumes reinforced concrete members are designed such that the effective tensile strength of the reinforced concrete member is at least equal to the compressive strength of the concrete material. This assumption is a standard design practice for reinforced concrete members which was validated by review of structural drawings.

The maximum shear stress in reinforced concrete members was observed in the x-y plane (i.e., horizontal plane) of the operating deck. The shear stresses were compared against the nominal shear capacity of the slab based on ACI 318-71.

Structural joints that connect girders to columns and other girders are not represented in the finite element model. As such, they were evaluated separately to ensure they will not fail during the design tornado event. Conservatively, the joint failure criteria based on AISC 360-16 was used for joint stress evaluations.

Finally, to ensure general building stability, the lateral drift ratios were estimated and conservatively compared against the allowable drift ratio of 1% based on guidance provided in ASCE 7-10 and ASCE 43-05.

6. *Section 3.3.2.1 (Building Stability)*

Explain the lateral resistant structural system and its evaluation.

Dominion Energy Virginia Response

The lateral load resisting system of the TB is comprised of several structural members, as listed below, that transfer the applied tornado wind loads to the TB foundation and eventually to ground:

- Roof truss members, prior to collapse, as well as structural steel members and reinforced concrete slabs of the operating and mezzanine decks, perform as rigid or partially rigid diaphragms and transfer the lateral tornado wind load horizontally through the roof or floor plane to other lateral load resisting members.

- Braced frames located on column lines 1 and 17 of the TBSS, as well as braced frames located between column lines 3 and 4 and between column lines 12 and 13 all acting in the north-south direction, resist the applied lateral loads in the north-south direction.

- Braced frames located on column lines B and C of the TBSS acting in the east-west direction provide lateral resistance in the east-west direction.

- Steel outriggers (braces) located on the north side of the TB provide additional lateral support for the upper portions of columns C7, C8, C9, and C10 along the north-south direction prior to roof collapse.

- Turbine pedestals provide significant lateral load support for the TBSS once the existing construction gaps between the pedestals and the operating or mezzanine decks are closed. The turbine pedestals are large, heavily reinforced concrete pedestals that extend from the TB foundation to the operating deck and support the weight of the turbines. When the TBSS undergoes lateral deformations due to the applied tornado wind load, the existing construction gaps between turbine pedestals and the operating or mezzanine decks would close, the decks would bear against the turbine pedestals, and the lateral load will be transferred to the pedestals and eventually to the reinforced concrete foundation.

- Reinforced concrete foundations of structural steel framings and turbine pedestals withstand the shear force caused by the tornado wind load and transfer it to the ground.

The finite element model of the TBSS included structural members resisting the lateral load, including structural steel and reinforced concrete members representing the operating and mezzanine decks and steel bracings (items 1, 2 and 3 in the above list).

Roof trusses (item 1) and steel outriggers (item 4) were removed from the model because preliminary analyses showed the roof of the TB cannot withstand the applied load due to a 250 mph tornado wind and would collapse.

The lateral support provided by the turbine pedestals (item 5) was included in the finite element model of the TBSS using node to node contact elements which incorporate a gap. At each supported concrete or steel node, a corresponding ground node which is fixed in all degrees of freedom (DOFs) was created. Contact elements were then created between supported nodes and the ground node. These contacts only close when the directional gap corresponding to the distance between the turbine pedestal and the supported bodies is closed. After gap closure, supported nodes are restrained only in the direction of the turbine pedestal, thus acting as a compression only support. The turbine pedestals were considered as rigid elements during the analysis due to their large size and reinforcement details.

As described in Section 3.3.2 of the LAR, the maximum lateral drift ratio of the operating floor slab (elevation 58'-6") was evaluated and found to be smaller than the acceptable drift ratio (i.e., the ratio of the lateral displacement of the operating floor to the vertical distance from the operating floor to the basement) of 1% (i.e., 0.70% for the east wind and even smaller for other wind directions.) Therefore, the TBSS is demonstrated to remain stable and not collapse under a 250 mph maximum tornado wind speed. Additionally, structural steel members were evaluated based on their stress and strain values created under the applied loads. The maximum stress and strain in all structural steel members comprising the TBSS, including those members that provide lateral load resistance, were determined to meet the acceptance criteria defined in Section 3.3.1.4 of the LAR. The reinforced concrete slabs of the operating and mezzanine decks were evaluated based on their compressive strength and shear capacity and found to meet the acceptance criteria described in Section 3.3.1.4 of LAR as well.

7. <u>Section 3.3.2.3 (Concrete Evaluation)</u>

LAR Section 3.3.2.3 states "The analysis results indicated the maximum shear stresses exceed the shear capacity of the concrete alone only at highly localized areas on the operating floor. These localized exceedances will not cause gross failure of the concrete floor since any excessive load would be redistributed into the more ductile rebar and surrounding steel." The staff reviewed "Surry Turbine Building Superstructure Evaluation for Tornado Wind Loads" (Calculation Number: 0114-0126-CALC-001, Revision 1), and found that the ratio of the maximum shear stress (426 psi) over the shear capacity of the concrete alone (123 psi) equals to 3.46. Provide the justification how this excessive shear load can be resisted by the rebar and surrounding steel. Provide the evaluation of reinforcing steel in the concrete, including the ratio of maximum compressive or tensile strength over their compressive or tensile capacity of the reinforcing steel.

Dominion Energy Virginia Response

In response to the NRC reviewer's questions, a minor clarification is required. The maximum shear stress in the SPS TB operating deck concrete slab was identified by the NRC reviewer to be 426 psi. According to the referenced Calculation No. 0114-0126-CALC-001, Rev. 1, the maximum shear stress reported in the operating deck slab is vmax = 630.5 psi, which occurs at one of the corner nodes in the finite element (FE) model. The reported total shear stress capacity of the 9-inch thick, reinforced concrete operating deck slab, vu max = 426.297 psi, is the sum of the concrete nominal shear stress capacity, vc = 123 psi, plus the available steel nominal shear stress capacity. Therefore, the highest interaction ratio for shear stress in the operating deck concrete slab, I.R. = vmax / vu max = 630.5 psi / 426.297 psi = 1.48 versus 3.46, as reported in the US NRC Audit Question 7 above. While an interaction ratio of 1.48 is less severe than 3.46, it still represents an instance of overstress that warrants further explanation.

The reported maximum shear stress in the calculation refers to the horizontal in-plane shear stresses in the operating deck due to the lateral tornado wind load. The operating deck of the TB is reinforced with longitudinal bars along two perpendicular directions on the top and bottom surfaces of the slab that prevent progression of shear cracks in the slab. Therefore, for horizontal in-plane shear forces, the total shear capacity of the slab would be more than the capacity provided by concrete alone due to the presence of the reinforcing mesh in the slab. The horizontal shear capacity of the operating deck slab is calculated to be equal to 426 psi when the contribution of the reinforcing bars in the slab is considered.

Although 1.48 is the highest calculated shear stress interaction ratio in the operating deck slab, it is not the only instance where calculated shear stress exceeds the total shear stress capacity of the operating deck slab, vu max = 426.297 psi. There are other similar locations where the maximum shear stresses in the reinforced concrete slab are found to exceed vu max = 426.297 psi based on finite element analysis results. All these instances of maximum shear stress occur as a result of numerical stress singularities (i.e., "hotspots"), which are not uncommon in FE models featuring sharp corners or geometric discontinuities at boundary locations. The observed numerical stress singularities in the model occur because the stress component at interface elements that are in the vicinity of sharp corners or geometric discontinuities approaches infinity when the corresponding force is numerically distributed over a very small area. This is validated by a follow-on observation that the magnitude of the maximum localized stress increases with mesh refinement. Exceeding the shear capacity at these localized areas is not fundamentally an issue. The stresses at these locations are self-limiting (i.e., the stresses in these localized areas are limited to the strains at which concrete cracks) and if high deformations or localized cracking were to occur, these high local stresses would redistribute over adjacent, less stressed areas, engaging the available shear capacity of reinforcing, thus lowering the average shear stress in the aggregate model. Applicable industry codes and standards for reinforced concrete structures, such as ACI-318,

recognize this behavior and permit aggregate forces and moments to be averaged across a given section to calculate capacity and demand on a member basis.

To provide a quantitative basis upon which to accept these localized "hotspot" shear stresses, the calculated shear stresses at the corner nodes of the elements immediately adjacent to the "hotspot" element in the operating deck slab were averaged and then compared to the total shear stress capacity of the 9-inch thick, reinforced concrete operating deck slab, vu max = 426.297 psi. In all cases, these average shear stresses were less than vu max. The highest average shear stress in the operating deck concrete slab was v avg = 406 psi, which results in a maximum I.R. = v avg / vu max = 406 psi / 426 psi = 0.95 < 1.0, which is acceptable.

NRC PROBABILISTIC RISK ASSESSMENT AUDIT INFORMATION REQUESTS:

Dominion Energy Virginia Risk Insight Summary:

The original LAR stated that safe shutdown components in the TB basement would not be impacted by the partial collapse of the TB roof. The NRC staff subsequently requested risk insights relative to any components, safety related or otherwise, that are important to risk and located in the TB.

Since the postulated failure mode being evaluated is damage caused by partial TB collapse, debris, or tornado missiles, the reliability data of modeled components is not relevant to this review. Therefore, Risk Achievement Worth (RAW) was selected as the risk importance metric for evaluating whether components are risk significant based on the consequences of failures.

A major tornado is likely to cause a general plant transient (GPT) and a loss of offsite power (LOOP). Therefore, the GPT (%U1-GPT and %U2-GPT) and weather-related LOOP (%LOOP-WR) initiating events were selected to represent the sequences related to the postulated tornado.

The base cutsets from the SPS-R06f PRA model were modified to represent Conditional Core Damage Probability (CCDP) and Conditional Large Early Release Probability (CLERP) of transients and LOOPs by setting all initiating event frequencies to zero except for the frequency of the event being examined, which was set to 1.0.

CAFTA was used to generate importance data for each of the cutset files. Each basic event represented in each cutset importance data report was associated with mark number and plant location data. Components with known mark numbers and plant locations were filtered down to those located in the turbine building. Components without assigned mark numbers or plant locations, including common cause failures, were reviewed for inclusion along with components that are known to be located in the TB. All

basic events with a RAW value of 2.0 or higher were reviewed. The following basic events were identified as risk significant:

Based on U1 LOOP CCDP RAW:
- 01-CN--150-VALVE
- 01-CN--622-VALVE
- 01-CN--151-CKVALV

Based on U1 Plant Trip CCDP RAW:
- 1-FW-P-1A
- 1-FW-P-1B

Based on U2 LOOP CCDP RAW:
- 02-CN--150-VALVE
- 02-CN--622-VALVE
- 02-CN--151-CKVALV

Based on U2 Plant Trip CCDP RAW:
- 2-FW-P-1A
- 2-FW-P-1B

The top CCDP cutsets related to the components identified as risk significant were reviewed, and the following general insights were identified:

Six valves in the Condensate (CN) system were identified that are risk significant in LOOP sequences because they are in the flow path used to provide extended Auxiliary Feedwater (AFW) supply after the eight (8) hours of AFW inventory in the Emergency Condensate Storage Tank (ECST) is depleted. A review was performed of the area in the TB where these valves are located, and it was determined that these valves would not be impacted by the postulated tornado and roof collapse described in the LAR. This means operators would still be able to access the location of these valves and perform the required steps to provide extended AFW supply to the ECST from the Condensate Storage Tank (CST) by manipulating 1-CN-150 for Unit 1 or 2-CN-150 for Unit 2. The path to the valves from the control room is not specified in a procedure, but there would be enough time for an operator to find an alternate path if the first choice were somehow obstructed. The time frame is favorable because the ECST has enough initial AFW inventory to last 8 hours meaning operators would not have to access these valves while the tornado event was still on site. Furthermore, if the CST, which is not a missile protected component, were impacted by the postulated tornado or tornado missiles, SPS has additional sources of long term AFW available from the fire main and the missile protected Emergency Condensate Make Up Tanks 1/2-CN-TK-3. These six CN valves were not in the scope of the Tornado Missile Risk Evaluation (TMRE) because they are not associated with a missile protection non-compliance.

The four Main Feedwater (MFW) pumps (1/2-FW-1A and 1B) are important in plant transient sequences where the control rods fail to insert leading to an Anticipated Transient Without Scram (ATWS) event that requires MFW for secondary heat removal. These motor-driven pumps have a RAW from internal events greater than 2.0 because a plant transient has a high frequency, on the order of E-1, but a tornado in the range of what is being discussed in this LAR (between 250 mph and 360 mph) has a frequency on the order of E-7. Therefore, a tornado induced ATWS would be considered too unlikely to be risk significant for the external event in the scope of this analysis. Additionally, a tornado of this magnitude would very likely cause a LOOP, which would render the MFW pumps inoperable, meaning they would not be available for use even if an ATWS did occur.

The operator actions credited in the PRA model that are performed locally in the TB were also reviewed. The only operator action that is risk significant for a plant trip or LOOP sequence is the action to refill the ECST from the CST using the CN valves discussed above. As previously confirmed, this action would still be able to be performed following the postulated tornado and TB roof failure described in the LAR.

In addition to the components identified by reviewing LOOP and transient cutsets, there are valves and piping in the CW and SW systems in the TB that are important to risk because they are potential sources of flooding in the TB basement. If a flood in this area cannot be isolated prior to propagation, it could impact equipment in the Emergency Switchgear Room (ESGR). As described in the LAR, components which could cause an unisolable flood would not be adversely impacted by the postulated roof collapse. This means the proposed design basis change does not increase the likelihood of a major unisolable flood in the Turbine Building. All isolable flood sources have not been explicitly screened, but roof collapse was a consideration in the original design considerations, so all isolable flood sources are either protected from damage by roof collapse by the structure above them or could be successfully isolated before flood propagation.

NRC PRA Audit Requests:

1. *Provide procedures governing the safe shutdown of the plant after a tornado, including a potential roof collapse scenario.*

Dominion Energy Virginia Response

Normal plant emergency operating procedures, abnormal operating procedures, and operating procedures would be used in the event of a tornado that caused the TB roof to collapse. On a plant trip, operators would enter 1/2-E-0, "Reactor Trip or Safety Injection," for the initial response to establish and confirm safe shutdown conditions. If offsite power were lost, operators would enter 1/2-AP-10.07, "Loss of Unit 1/2 Power," for a loss of station power. The actions required by these procedures are conducted in the Main Control Room (MCR) and would not be impacted by postulated TB damage.

After the initial supply of AFW in the ECST is depleted, if the CST was available, operators would need to use 1/2-OP-FW-006, "Filling Emergency Condensate Tanks 1-CN-TK-1 and 1-CN-TK-3," to provide additional long term AFW supply to the AFW pumps from the ECST. As noted above, this procedure requires manipulation of the valve 1/2-CN-150 to provide AFW from the CST to the ECST. The performance of this procedure would not be impacted by damage caused to the TB from the tornado postulated in this application.

2. *Availability of equipment required to achieve and maintain safe shutdown conditions after a potential roof collapse scenario.*

Dominion Energy Virginia Response

The availability of the MFW pumps and the CN valves identified would not be impacted by the postulated roof collapse. The location of these components and the associated piping would prevent them from being damaged and would permit operators to use this equipment if needed for safe shutdown following a tornado. Additionally, the availability of valves needed to isolate potential flood sources in the TB would not be impacted by the postulated roof collapse.

3. *Qualitative or quantitative risk insights based on the evaluation of a potential roof collapse scenario and their impact on the application.*

Dominion Energy Virginia Response

As described in the risk summary, the key risk insights associated with the postulated tornado and roof collapse described in this application are as follows:

- Key equipment located in the TB would remain available and allow for operators to safely shut down the reactors in the event of a dual unit trip or loss of offsite power.
- Risk significant unisolable flood sources in the TB basement that could cause a flood that impacts emergency switchgear will not be impacted. Isolable flood sources that have not been explicitly screened for shielding could be isolated if necessary.
- The frequency of a tornado event that is above the proposed design basis limit of 250 mph and below the original design basis limit of 360 mph is very low, on the order of 1E-7 events per year.

4. *The SSCs in the turbine building basement that were evaluated by the TMRE methodology.*

Dominion Energy Virginia Response

The following components in the Turbine Building basement were evaluated by the TMRE Methodology:

- Unit 1 Condenser inlet valves 1-CW-MOV-106A/B/C/D

- Unit 1 A SW Valve Pits containing the following valves:
  - 1-SW-MOV-103A/B/C/D, 1-SW-MOV-101A/B, 1-SW-54 and 1-SW-41

- Unit 1 B SW Valve Pits containing the following valves:
  - 1-SW-MOV-102A/B and 1-SW-495

- Unit 1 Manways 1-CW-FNG-1/2/4 (30" Access to 96" A/B/D CW Inlet Piping)

- Unit 2 Condenser inlet valves 2-CW-MOV-206A/B/C/D

- Unit 2 A SW Valve Pit containing the following valves:
  - 2-SW-MOV-203A/B/C/D, 2-SW-MOV-201A/B, 2-SW-11 and 2-SW-474

- Unit 2 B and C SW Valve Pits containing the following valves:
  - 2-SW-MOV-202A/B

- Unit 2 Manways 2-CW-FNG-101/2/3/4 (30" Access to 96" A/B/C/D CW Inlet Piping)

Dominion Energy Virginia PRA Conclusion

The risk insights associated with the proposed TB Tornado Wind Loading LAR have been examined as described above. The risk impact associated with this LAR is minimal because the components that may be needed in response to the postulated tornado will still be available in the case of TB roof collapse. This means operators would be able to respond effectively to the proposed design basis tornado of 250 mph to safely shut down and maintain the reactors in a safe condition if required.